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(71) Applicant: QUALCOMM INCORPORATED [US/US]; 6455 Lusk Boulevard, San Diego, CA 92121 (US).

(72) Inventors: TIEDEMANN, Edward, G., Jr.; 4350 Bromfield Avenue, San Diego, CA 92122 (US). CHEN, Tao; 8826 La Cartera Street, San Diego, CA 92129–3309 (US). WHEATLEY, Charles, E., III; 2208 Caminito Del Barco, Del Mar, CA 92014 (US).

(74) Agents: MILLER, Russell, B. et al.; Qualcomm Incorporated, 6455 Lusk Boulevard, San Diego, CA 92121 (US).

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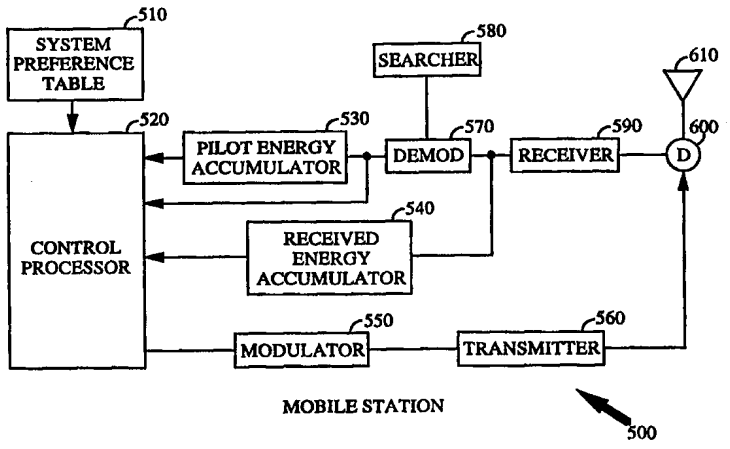

(57) Abstract

A method and apparatus for performing inter–system hard handoff between communication systems (S1, S2) or inter–frequency hard handoff within a CDMA communication system is disclosed. The purpose of this invention is to reduce the probability of dropped calls during intersystem hard handoff. In the event that a hard handoff attempt is unsuccessful, the mobile station (18) will return to the original system (S1) with information which the communication system of the present invention uses to assist in the performance of future handoff attempts. Alternatively, with no handoff attempt made, the mobile station (18) monitors the destination system (S2), then returns to the original system (S1) with information used to assist in subsequent handoff attempts. The information returned from monitoring a CDMA system consists of results of a search for one or more pilots given at offsets in a specific list provided to the mobile station (18) by the base station (B1–B5) or a set of offsets based upon a predetermined search algorithm.

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METHOD AND APPARATUS FOR PERFORMING MOBILE ASSISTED HARD HANDOFF BETWEEN COMMUNICATION SYSTEMS

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to communications systems. More particularly, the present invention relates to a novel and improved method for hard handoff between different wireless communication systems.

II. Description of the Related Art

In a code division multiple access (CDMA) spread spectrum communication system, a common frequency band is used for communication with all base stations within that system. An example of such a system is described in the TIA/EIA Interim Standard IS-95-A entitled "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System", incorporated herein by reference. The generation and receipt of CDMA signals is disclosed in U.S. Patent No. 4,401,307 entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEMS USING SATELLITE OR TERRESTRIAL REPEATERS" and in U.S. Patent No. 5,103,459 entitled "SYSTEM AND METHOD FOR GENERATING WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM" both of which are assigned to the assignees of the present invention and incorporated herein by reference.

Signals occupying the common frequency band are discriminated at the receiving station through the spread spectrum CDMA waveform properties based on the use of a high rate pseudonoise (PN) code. A PN code is used to modulate signals transmitted from the base stations and the remote stations. Signals from different base stations can be separately received at the receiving station by discrimination of the unique time offset that is introduced in the PN codes assigned to each base station. The high rate PN modulation also allows the receiving station to receive a signal from a single transmission station where the signal has traveled over distinct propagation paths. Demodulation of multiple signals is disclosed in U.S. Patent No. 5,490,165 entitled "DEMODULATION ELEMENT ASSIGNMENT IN A SYSTEM CAPABLE OF RECEIVING MULTIPLE SIGNALS" and in U.S. Patent No. 5,109,390 entitled "DIVERSITY RECEIVER

IN A CDMA CELLULAR TELEPHONE SYSTEM", both of which are assigned to the assignee of the present invention and incorporated herein by reference.

The common frequency band allows simultaneous communication between a remote station and more than one base station, a condition known as soft handoff disclosed in U.S. Patent No. 5,101,501 entitled "SOFT HANDOFF IN A CDMA CELLULAR TELEPHONE SYSTEM" and U.S. Patent No. 5,267,261 entitled "MOBILE STATION ASSISTED SOFT HANDOFF IN A CDMA CELLULAR COMMUNICATIONS SYSTEM", both assigned to the assignee of the present invention and incorporated herein by reference. Similarly, a remote station can be simultaneously communicating with two sectors of the same base station, known as softer handoff as disclosed in copending U.S. Patent Application entitled "METHOD AND APPARATUS FOR PERFORMING HANDOFF BETWEEN SECTORS OF A COMMON BASE STATION", Ser. No. 08/405,611, filed March 13, 1995, assigned to the assignee of the present invention and incorporated herein by reference. Handoffs are described as soft and softer because they make the new connection before breaking the existing one.

If a mobile station travels outside the boundary of the system with which it is currently communicating, it is desirable to maintain the communication link by transferring the call to a neighboring system, if one exists. The neighboring system may use any wireless technology, examples of which are CDMA, NAMPS, AMPS, TDMA or FDMA. If the neighboring system uses CDMA on the same frequency band as the current system, an inter-system soft handoff can be performed. In situations where inter-system soft handoff is not available, the communication link is transferred through a hard handoff where the current connection is broken before a new one is made. Examples of hard handoffs are those from a CDMA system to a system employing an alternate technology or a call transferred between two CDMA systems which use different frequency bands (inter-frequency hard handoff).

Inter-frequency hard handoffs can also occur within a CDMA system. For example, a region of high demand such as a downtown area may require a greater number of frequencies to service demand than the suburban region surrounding it. It may not be cost effective to deploy all available frequencies throughout the system. A call originating on a frequency deployed only in the high congestion area must be handed off as the user travels to a less congested area. Another example is that of a microwave or other service operating on a frequency within the system's boundaries. As

users travel into an area suffering from interference from the other service, their call may need to be handed off to a different frequency.

Handoffs can be initiated using a variety of techniques. Handoff techniques, including those using signal quality measurements to initiate handoff , are found in copending U.S. Patent Application number 08/322,817 entitled "METHOD AND APPARATUS FOR HANDOFF BETWEEN DIFFERENT CELLULAR COMMUNICATIONS SYSTEMS", filed October 16, 1994, assigned to the assignee of the present invention and incorporated herein by reference. Further disclosure on handoffs, including measurement of round-trip signal delay to initiate handoff, is disclosed in copending U.S. Patent Application number 08/652,742 entitled "METHOD AND APPARATUS FOR HARD HANDOFF IN A CDMA SYSTEM", filed May 22, 1996, assigned to the assignee of the present invention and incorporated herein by reference. Handoffs from CDMA systems to alternate technology systems are disclosed in copending U.S. Patent Application number 08/413,306 ('306 application) entitled "METHOD AND APPARATUS FOR MOBILE UNIT ASSISTED CDMA TO ALTERNATIVE SYSTEM HARD HANDOFF", filed March 30, 1995, assigned to the assignee of the present invention and incorporated herein by reference. In the '306 application, pilot beacons are placed at the boundaries of the system. When a mobile station reports these pilots to the base station, the base station knows that the mobile station is approaching the boundary.

When a system has determined that a call should be transferred to another system via hard handoff, a message is sent to the mobile station directing it to do so along with parameters that enable the mobile station to connect with the destination system. The system has only estimates of the mobile station's actual location and environment, so the parameters sent to the mobile station are not guaranteed to be accurate. For example, with beacon aided handoff, the measurement of the pilot beacon's signal strength can be a valid criteria for triggering the handoff. However, the appropriate cell or cells in the destination system which are to be assigned to the mobile station (known as the Active Set) are not necessarily known. Moreover, including all the likely possibilities may exceed the maximum allowable in the Active Set.

In order for the mobile station to communicate with the destination system, it must lose contact with the old system. If the parameters given to the mobile station are not valid for any reason, i.e. changes in the mobile station's environment or lack of precise location information at the base station, the new communication link will not be formed, and the call may

be dropped. After an unsuccessful handoff attempt, the mobile station can revert back to the previous system if it is still possible to do so. With no further information and no significant change in the mobile station's environment, repeated attempts to hand off will also fail. Thus, there is a need felt in the art for a method for performing additional hard handoff attempts with greater probability of success.

SUMMARY OF THE INVENTION

The purpose of this invention is to reduce the probability of dropped calls during inter-system hard handoff. In the event that a hard handoff attempt is unsuccessful, the mobile station will return to the original system with information which the communication system of the present invention uses to assist in the performance of future handoff attempts.

Prior to handoff, the original base station will have a rough estimate of the most likely base stations of a destination system to provide service to a mobile station as it travels into the destination system. In the exemplary embodiment, a message will be sent from the base station to the mobile station containing this list of neighboring base stations in the destination system, a minimum total received power threshold, and a minimum pilot energy threshold. When the base station in the original system has determined that a hard handoff is appropriate, it signals the neighboring base stations in the destination system to begin transmitting forward link traffic to the mobile station entering the system. A first hard handoff is attempted after a message is received by the mobile station from the base station initiating the inter-system hard handoff. The mobile station switches to the frequency of the destination system and attempts to acquire the base stations of the destination system in accordance with the acquisition parameters provided (i.e. the pilot PN offsets). If the minimum pilot energy threshold is exceeded, the handoff is deemed to be successful and the mobile station remains on the destination system.

If the minimum pilot energy threshold is not exceeded, recovery techniques begin. The mobile station measures the total in-band energy of the destination system and compares that to the total received power threshold. If the minimum total received power threshold is not exceeded, the handoff is abandoned immediately. The mobile station returns to the original system and reports that no significant power was detected at the new frequency. If the minimum total received power is exceeded, it is likely that the destination system is available, but that the neighboring base

stations provided by the original system (referred to as the new Active Set) is not acceptable for communication. The mobile station then performs a search to locate viable pilot signals in the destination system. In general, a list of offsets to search provided to the mobile station will be sufficient to locate available pilots, although other search algorithms can be employed. Upon completion of the search, the mobile station returns to the original system and reports the failure and any pilot signals found in the search which exceeded a third threshold.

If no significant received power was detected or there were no pilots found in the search, the system controller can opt to delay a second attempt at handoff in hopes of a beneficial change in the mobile station's environment. In the alternative, the mobile station can abandon the hard handoff attempt altogether, which would likely result in the eventual dropping of the call. However, in those cases where the destination system is present, the system controller can update the Active Set based on the returned search information, and the destination system can modify the base stations transmitting to the mobile station accordingly. Then a second hard handoff attempt message can be sent to the mobile station. Unless the environment has changed, this second attempt is likely to be successful.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a schematic overview of an exemplary spread spectrum CDMA communications system in accordance with the present invention;

FIG. 2 is a representation of example scenarios whereby the various situations responded to by this invention can be described;

FIG. 3 is an illustration of an exemplary base station;

FIG. 4 is an illustration of an exemplary mobile station; and

FIG. 5 is a flow chart illustrating the operation of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 depicts an embodiment of a communication system employing the present invention. A typical CDMA communications system consists of a system controller and switch **10** in communication with one or more base stations, examples of which are **12, 14,** and **16**. System controller and switch **10** also connects with the Public Switched Telephone Network (PSTN) (not shown) and with other communication systems (not shown). Mobile station **18** is an example subscriber with forward links **20B, 22B,** and **24B,** and reverse links **20A, 22A,** and **24A**. The system controller and switch **10** controls soft handoffs and inter-frequency hard handoffs within the system, and in conjunction with neighboring systems controls inter-system soft handoff as well as inter-system hard handoffs. The exemplary embodiment of the present invention deals with CDMA system to CDMA system inter-frequency hard handoffs. It will be understood by one skilled in the art that the teachings of the present invention can be applied to handoffs using multiple access schemes and for handoff between systems using different modulation schemes.

FIG. 2 depicts three different scenarios possible in the use of the present invention. Three mobile stations, **M1, M2,** and **M3** are traveling from the system where their respective calls originated, **S1,** to a neighboring system of differing frequency, **S2**. Initially, all the mobile stations **M1 - M3** are in communication with one or more base stations (not shown) in system **S1**. As each mobile station travels across the boundary of **S1** into **S2,** a hard handoff attempt will be made. The destination system, **S2,** contains base stations **B1 - B5** each which cover a cell area **C1 - C5,** respectively. System **S2** may have other base stations (not shown) which do not affect the scenarios given. As shown, some cells intersect with other cells. In that overlapping region, a mobile station can be in communication with either base station or both simultaneously if the mobile station is in soft handoff. Also shown are obstructions **O1 - O3**. These obstructions distort the coverage areas that otherwise would be circular shaped cells. Cell **C5** is shown shaded to clearly indicate its unusual shape.

Consider first mobile station **M1**. This is an example of a case which would result in a successful hard handoff in both the state of the art and the current invention. As **M1** approaches the **S1 - S2** border, origination system **S1** predicts the likely neighbors in destination system **S2,** based on its best guess of the location of **M1**. **S1,** through a base station in contact with **M1**

(not shown) then notifies **M1** of the PN offsets of cells in the destination system **S2**, for example **C1**, **C2**, **C3**, **C4**, and **C5**. In the exemplary embodiment, **S2** also sends parameters for minimum total received pilot, MIN_TOT_PILOT, and minimum received power, MIN_RX_PWR. In an alternative embodiment, **M1** may store values of MIN_TOT_PILOT and MIN_RX_PWR or may be capable of generating the values based on system data. **S1** then begins forwarding traffic to system **S2** with instructions to set up the appropriate forward link for that data directed to mobile station **M1** on base stations **B2** and **B3**. Base stations **B2** and **B3** are the most likely target base stations and are in the new Active Set. Then **S1** sends an initiation message to mobile station **M1** to begin the hard handoff process. Owing to the benign propagation environment in the vicinity of mobile station **M1**, when **M1** switches to the new frequency, it will find the pilots and successfully demodulate forward link traffic from the new Active Set, base stations **B2** and **B3**, as predicted by system **S1**. **M1** determines the hard handoff to be successful because the total received pilot exceeds the threshold MIN_TOT_PILOT. System **S1** will deallocate resources previously assigned to communicate with mobile station **M1** after it is determined that the hard handoff was successful. This determination may be made by receipt of a message from system **S2**, or based on a prearranged time duration in which no further communication takes place between system **S1** and mobile station **M1**.

Next, consider mobile station **M2**, which is in an area of inadequate coverage by **S2** often referred to as a hole. As mobile station **M2** approaches the **S1** - **S2** border, system **S1** predicts that coverage in system **S2** is provided in cell **C1**. The handoff is initiated in the same manner as described above. However, upon switching to the frequency of destination system **S2**, significant signal energy is not received by mobile station **M2** due to the interference caused by obstruction **O3**. That is, total received pilot is less than the threshold MIN_TOT_PILOT. In current systems, this call would be dropped. In the present invention, the mobile station begins recovery techniques.

Once the mobile station determines that the pilot or pilots predicted by **S1** are not available, **M2** measures the total received power in the new frequency band and compares it to threshold MIN_RX_PWR. In this example, the only transmitter near **M2** is base station **B1** and its signal is blocked by obstruction **O3**, so no significant energy is found in the frequency band of the destination system. Mobile station **M2** then abandons the handoff and returns to system **S1**, notifying it that no system **S2** was found.

Assume mobile station **M2** continues traveling away from system **S1**. Since the call was not dropped, as would have been the case using current methods, a number of options exist. At minimum, the call can continue on system **S1** until it eventually drops because the distance has become too great. Given that the mobile station environment is susceptible to change, a second handoff attempt after a delay may be successful.

Finally, consider mobile station **M3**. In like manner to mobile stations **M1** and **M2** handoff procedures are initiated with cells **C1** and **C2** being the predicted new Active Set. Due to obstructions **O1** and **O2**, neither predicted cell is available to mobile station **M3**, hence MIN_TOT_PILOT is not exceeded. Again recovery procedures begin. This time base station **B5** is within range, however its offset is not in the new Active Set, nor is it transmitting forward link data directed to **M3**. As such, although the predicted cells are not available, the minimum received power threshold, MIN_RX_PWR, is exceeded. In the exemplary embodiment of the present invention, since the system appears to be available, a search for available pilots is performed. When the search is complete, mobile station **M3** returns to system **S1** and notifies it of the failed handoff attempt as well as the available pilots, in this case the pilot for cell **C5**. In the present invention, **S1** sends a message to destination system **S2** to set up a forward link on base station **B5**, then a second attempt at handoff can be made. If the environment has not changed substantially, the second time **M3** switches to the new frequency, the call will successfully hand off to base station **B5** of destination system **S2**.

FIG. 3 depicts an exemplary base station. Base station **300** communicates with other systems (not shown) and with system controller and switch **10**, shown in FIG. 1, through system interface **310**. Inter-frequency handoff is a distributed process, with system controller and switch **10** signaling with the other switch, and base station **300** handling some of the handoff details. System controller **10** determines, in conjunction with base station **300**, that an inter-system hard handoff is necessary. There are many alternatives for handoff determination as described above, including mobile station location or pilot beacon reception. The destination system (not shown) is instructed by the origination system to begin transmitting forward link traffic on the destination system's frequency from a select set of base stations. A database (not shown) in control processor **360** may contain the candidate base stations. Alternatively, a suitable list of handoff base station candidates can be returned from the destination system to control processor **360** through system interface **310**. In situations where the destination system

is not a CDMA system, other parameters useful for acquiring the destination system can be delivered to control processor **360** through system interface **310**.

Parameters and instructions from control processor **360** are formed into messages in message generator **320**. Those messages are modulated in modulator **330** and sent to the mobile station through transmitter **340** and antenna **350**. In the exemplary embodiment, modulator **330** is a CDMA modulator as described in the aforementioned U.S. Patent Nos. 4,901,307 and 5,103,459. In the exemplary embodiment, the list of neighbor base stations, MIN_TOT_PILOT, and MIN_RX_PWR are combined into a single message, referred to herein as the Other Frequency Neighbor List Message (OFNLM). The base station to mobile station message that signals the mobile station to begin attempting to acquire the destination system contains the destination system Active Set and is called the Extended Handoff Direction Message (EHDM). Additional parameters are envisioned that could be sent to the mobile station to facilitate improved hard handoff in the event of a handoff attempt failure. For example, a specific list of offsets to search, a range of offsets to search, or a specific search algorithm such as searching offsets in increments of 64 chips away from those offsets attempted from those of the base stations listed in the OFNLM.

Following a failed hard handoff attempt, the mobile station will follow the instructions as given, then return to the original system to communicate its findings. Reverse link signals from the mobile station to base station **300** are received through antenna **390**, downconverted in receiver **380**, and demodulated in demodulator **370** under control of control processor **360**.

FIG. 4 depicts an exemplary mobile station **500**. Messages arrive at control processor **520** from base station **300** through antenna **610**, duplexer **600**, receiver **590** and demodulator **570**. In the exemplary embodiment, receiver **590** is a CDMA modulator as described in the aforementioned U.S. Patent Nos. 4,901,307 and 5,103,459. Upon receipt of the EHDM message from base station **300**, control processor **520** directs receiver **590** and transmitter **560** to tune to the frequency of the destination. At this point, the communication link with the original system has been broken. Control processor **520** directs demodulator **570** to attempt to demodulate pilots at the offsets in the Active Set as given by base station **300** in the EHDM. The energy in the signals demodulated with those offsets is accumulated in pilot energy accumulator **530**. Control processor **520** uses the results of the accumulation to compare to MIN_TOT_PILOT. If MIN_TOT_PILOT is

exceeded, the handoff is deemed successful. If MIN_TOT_PILOT is not exceeded, recovery operations begin. Alternatively, a requirement of receiving some number N good frames (no CRC errors) within a specific time T can be used to determine if the handoff attempt is successful.

The first step following an unsuccessful hard handoff attempt is to determine if the destination system is available. Received energy accumulator **540** accumulates the total power received in the destination system's frequency band and provides the result to control processor **520**. Control processor **520** compares those accumulation results with the threshold MIN_RX_PWR. If MIN_RX_PWR is not exceeded, the handoff attempt is aborted. Receiver **590** and transmitter **560** are retuned to the original frequency and control processor **520** generates a message that notifies base station **300** that the handoff attempt failed and the destination system was not found to be significantly present. The message is provided to modulator **550** which modulates the message and provides the modulated signal through transmitter **560**, duplexer **600**, and antenna **610** for transmission.

Mobile station **500** contains system preference information stored in system preference table **510**. If the destination system is not present, mobile station **500** may send alternate system information to base station **300**, so that mobile station **500** may attempt to acquire a different system on the next hard handoff attempt. For example, a neighboring region may be covered by multiple systems, which may include a combination of CDMA systems as well as systems of alternate technologies. System preference table **510** may be programmed such that if a first preferred system is not available, acquisition of a second system is attempted. There may be additional systems upon which to attempt handoff, should the second system be unavailable. Handoff attempts can be made in a prioritized order until acquisition has been attempted on all candidate systems.

If MIN_RX_PWR is exceeded, indicating that the destination system is available, mobile station **500** proceeds as previously instructed. In the exemplary embodiment, searcher **580** conducts a search to locate pilot offsets where base stations in the destination system are available. To perform a search, searcher **580** generates the PN sequence with a specific offset. Demodulator **570** correlates the incoming data with the offset PN sequence. Pilot energy accumulator **530** measures the pilot energy for that offset by accumulating samples for a predetermined time interval. Control processor **520** compares that result to a threshold, called T_ADD, to determine whether a pilot is available for that offset. Searcher **580** then moves to the

next offset candidate. The process repeats until there are no more candidate offsets to measure. The search operation process is described in detail in copending U.S. Patent Application Serial No. 08/509/721 entitled "METHOD AND APPARATUS FOR PERFORMING SEARCH ACQUISITION IN A CDMA COMMUNICATION SYSTEM", filed July 26, 1996, which is assigned to the assignee of the present invention and incorporated by reference herein. Alternate search algorithms can be substituted in searcher **580** without modification to the present invention.

The search subsequent to the hard handoff failure may be performed over all possible offsets or a subset thereof. For example, a range of offsets may be searched. In the exemplary embodiment, the OFNLM contains the subset of offsets to be searched. In the exemplary system, neighboring base stations are separated by integer multiples of 64 chips. If one base station offset in the system is known (even if it is not currently available), only offsets that are integer multiples of 64 from that known offset need to be searched in order to attempt acquisition on the complete set of neighbor base stations. A combination of spaced offsets in a specific range or number of ranges can also be searched.

When the destination system is an alternate technology, there may be different procedures to perform which will yield information that will improve subsequent hard handoff attempts. For example, when the destination system is TDMA, the mobile station may measure the in band energy at a plurality of frequency subbands and report this information to the origination system. Or in the case of a neighboring AMPS system, the base station can send an OFNLM specifying frequencies for the analog control channels. However, it may not be necessary to send the frequencies of the control channels if they are already known. In that case, if the mobile station finds the voice channel to which it was handed off is too weak, the mobile station can proceed to measure the received power on the analog control channels. It may also determine the digital color code (DCC) for the control channel. The DCCs provide better determination of the cell in case the mobile station might be able to receive multiple cells in an area. The frequencies and DCCs of the strongest analog base stations can be returned as information to assist with a subsequent handoff attempt. Further discussion of the use of DCCs can be found in chapter 3 of "Mobile Cellular Telecommunications Systems" by William C.Y. Lee.

After mobile station **500** completes the requisite tasks, receiver **590** and transmitter **560** are retuned to the original frequency and control processor **520** notifies base station **300** through modulator **550**, transmitter

560, duplexer 600, and antenna 610 that the handoff attempt failed and delivers any information that has been discovered during subsequent system search procedures.

The flow chart in FIG. 5 illustrates operation of the preferred embodiment of this invention. After determining that a handoff is imminent, the origination system predicts the list of neighbor base stations on the neighboring system's frequency in box 50. Proceed to 52, a base station in the origination system sends to the mobile station the Other Frequency Neighbor List Message (OFNLM) described above. In block 53, the Active Set for the new frequency is determined. In block 54, the destination system sets up the forward link as specified in the Extended Handoff Direction Message (EHDM). In block 56, the base station in the origination system sends the Extended Handoff Direction Message (EHDM) to the mobile station to initiate the inter-frequency hard handoff. Following that message, in 58, the mobile station tunes to the new frequency and attempts to acquire the destination system according to the Active Set information in the EHDM message.

In block 60, the mobile station measures the pilot energy, the sum of the energy of all pilots in the Active Set, and if the received total pilot energy exceeds that of parameter MIN_TOT_PILOT, proceed to 62, a successful hard handoff has occurred. The exemplary embodiment envisions that a mobile station is capable of being handed off directly into a soft handoff condition in the destination system, although that is not a requirement. A single pilot in the new Active Set whose received pilot energy exceeds that of parameter MIN_TOT_PILOT is sufficient for a successful handoff.

From 60, if MIN_TOT_PILOT is not exceeded, proceed to 68. In 68, if total received power in the frequency band exceeds parameter MIN_RX_PWR indicating the general presence of the destination system, proceed to 66, otherwise go to 69.

An alternative embodiment would be to check total received power before pilot energy. If the MIN_RX_PWR threshold is not exceeded, the handoff is aborted. This may be faster in some implementations.

In 66, search the possible offsets for available pilot signals. Any alternate search strategy can be performed here as well. When search is complete, proceed to 65. The mobile station returns to the original system in 65, then proceeds to 64. In 64, make necessary changes to OFNLM and return to 52, where the operation proceeds as described above.

In 69, the mobile station returns to the original system, then proceeds to 72. From 72, the decision can be made to continue attempting handoff by

proceeding to **70**, or the handoff procedure can be aborted by proceeding to **74**. An optional delay is introduced in **70**, then proceed to **64**.

In an alternative embodiment of the present invention, the base station sends the mobile station an extended list of base stations which may be available at the point in which the mobile station is entering the destination system. In this alternative embodiment, no forward links are immediately set up in the destination system. Rather the mobile station simply determines whether the strength of any of the signals provided by any of the extended list of candidate systems are adequate to support a communication link. The mobile station monitors the forward link signals of each of the base stations in the extended list of candidate base stations.

After monitoring the signal strength of each of base stations in the extended list of candidate base stations, the mobile station necessarily returns to the original system and sends a message indicating the signal strength of the forward links of the candidate base stations. In the exemplary embodiment, the mobile station compares the strength of the signals received by each of the base stations in the extended list to a predetermined threshold T_ADD and reports only whether the measured signal power is above or below the threshold.

The base station of the original system receives the information regarding the signal strength of each of the base stations in the destination system and from this information the base station of the original system generates an Active Set list. This list is provided to the destination system which sets up forward links for the mobile station in accordance with the Active Set list provided by the original system. The base station of the original system transmits the active list to the mobile station which attempts to acquire the base stations in the active list and, if acquisition is successful, transmission to the mobile station is available without interruption.

Referring to FIG. 2, the alternative embodiment will be described in terms of acquisition of mobile **M3**. When original system **S1** determines that mobile **M3** should begin hard hand off operations to destination system **S2**, the base station in original system **S1** which is currently in communication with mobile station **M3** generates an extended list of base stations in **S2** which the mobile station may be able to acquire. In the exemplary embodiment, the extended candidate list would likely consists of the parameters necessary to perform a search on all of base stations **B1**, **B2**, **B3**, **B4** and **B5**, as well as additional base stations in destination system **S2** (not shown). Note in the alternative embodiment, no information regarding **M3** has, as of yet, been provided to the destination system **S2**.

Mobile station **M3** tunes to the frequency of destination system **S2** and measures the energy on each of the pilot channels of the base stations in the extended candidate list. In the example of mobile station **M3**, the mobile station would transmit back a message to the base station on the original system **S1** a message indicating that acquisition upon base station **B5** was possible. In response to this message, the base station in the original system would generate an Active Set list consisting solely of base station **B5**.

The base station in the original system would send a message to the destination system **S2**, indicating that a forward link for the mobile station **M3** should be provide on base station **B5**. In response to this message, the destination system **S2** sets up a forward link for mobile station **M3** on base station **B5**. The Active Set list is sent to mobile station **M3**. In response to the Active Set message, mobile station **M3** attempts acquisition of base station **B5**.

Referring to FIG. 3, base station **300** of the original system generates an extended candidate list in message generator **320** and provides the message to modulator **330**. The message is modulated by modulator **330** and provided to transmitter **340** which upconverts and amplifies the signal and transmits the resulting signal through antenna **350**.

Referring to FIG. 4, the transmitted signal is received by mobile station **500** by antenna **610** and is downconverted, filtered and amplified by receiver **590**. The received signal is then demodulated by demodulator **570** and provided to control processor **520**. Control processor **520** then generates a set of commands directing a search to be performed by searcher **580**. Searcher **580** provides a set of search demodulation parameters to demodulator **570**. The demodulated signals are provided to pilot energy accumulator **530** which measures the strength of the pilots of the base stations of the extended candidate list. The energy of each of these candidates is provided to control processor **520** which compares the measured energy with a threshold T_ADD. Control processor **520** generates a message which signifies which, if any, of the candidate base station's signals exceed the threshold.

The message is provided to modulator **550** where it is modulated. The modulated signal is then provided to transmitter **560** where it is upconverted, amplified, and transmitted through antenna **610**.

Referring back to FIG. 3, the message indicating the strengths of the candidate base stations is received by antenna **390** of base station **300** of the original system. The signal is downconverted and amplified by receiver **380** and provided to demodulator **370**. Demodulator **370** demodulates the signal

and provides the result to control processor **360**. Control processor **360** generates an Active Set list for the destination system in accordance with the information in the message transmitted by mobile station **500** indicating the results of its search. In the exemplary embodiment, the Active Set list will consist of all base stations whose signals, when monitored by mobile station **500**, exceeded the energy threshold T_ADD.

Control processor **360** sends the Active Set list to system interface **310** which sends a message indicating the Active Set list to the destination system **S2**. Capacity issues allowing, destination system **S2** provides forward link channels on each of the systems in the Active Set list.

Control processor **360** also provides the Active Set list to message generator **320**. The resulting message is modulated by modulator **330** and transmitted as described above.

Mobile station **500** receives the message by antenna **610**, demodulates the signal as described above, and provides the message to control processor **520**. Control processor **520** then provides information regarding the Active Set list to demodulator **570** and receiver **590** and a hard handoff to the destination system **S2** is attempted using the parameters of the base stations in the Active Set list. It should be noted that because, in this example, the active list was determined by mobile station **500**, the mobile station need not receive the Active Set list, since it knows the station on the list apriori. Thus, in an alternative, embodiment, the mobile station may delay a predetermined time period and perform handoff to the base stations who's signals exceeded the threshold. If, on the other hand, the Active Set is not simply a copy of the base stations which exceeded the threshold but rather also takes into account parameters unknown to the mobile station, such as capacity parameters of **S2**, then transmission of the message would prove of value.

In a variation on the above described alternative embodiment, the mobile station periodically tunes to the new frequency and measures the offsets supplied in the OFNLM without direction from the base station. The period may be specified in the OFNLM. After the search is complete, the mobile station returns to the origination system and reports its findings. This information gained by polling the neighboring system can be used to determine the Active Set for a subsequent handoff attempt, as well as to assist in determining whether to initiate a handoff to that system.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to

those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WE CLAIM:

CLAIMS

1. In a wireless communication system wherein a mobile station is moving from the coverage area of an origination system into the coverage area of a destination system and wherein a first attempt to acquire said destination system has failed, a method for avoiding lost communication with said mobile station, comprising the steps of:

transmitting from said mobile station to said origination system a set of parameter data;

receiving at said origination system said parameter data;

generating at said origination system a search list in accordance with said parameter data; and

attempting by said mobile station to acquire said destination system in accordance with said second search list.

2. The method of Claim 1 further comprising the step of measuring said parameter data at said mobile station.

3. The method of Claim 2 wherein said step of measuring said parameter data comprises measuring the signal energy of pilot signals of said destination system.

4. The method of Claim 2 wherein said step of measuring said parameter data is performed in accordance with a predetermined set of search parameters.

5. The method of Claim 4 wherein said set of search parameters is transmitted to said mobile station by said origination system.

6. The method of Claim 1 further comprising transmitting said search list from said origination system to said mobile station.

7. In a wireless communication system wherein a mobile station is moving from the coverage area of an origination system into the coverage area of a destination system, a method for providing handoff from said origination system to said destination system, comprising the steps of:

transmitting from said origination system to said mobile station a set of search parameter data;

determining at said mobile station the availability of said destination system in accordance with said set of parameter;

transmitting from said mobile station to said origination system a message indicative of the availability of said destination system;

generating at said origination system a set of acquisition parameters in accordance with said message from said mobile station;

attempting at said mobile station to acquire said destination system in accordance with said set of acquisition parameters.

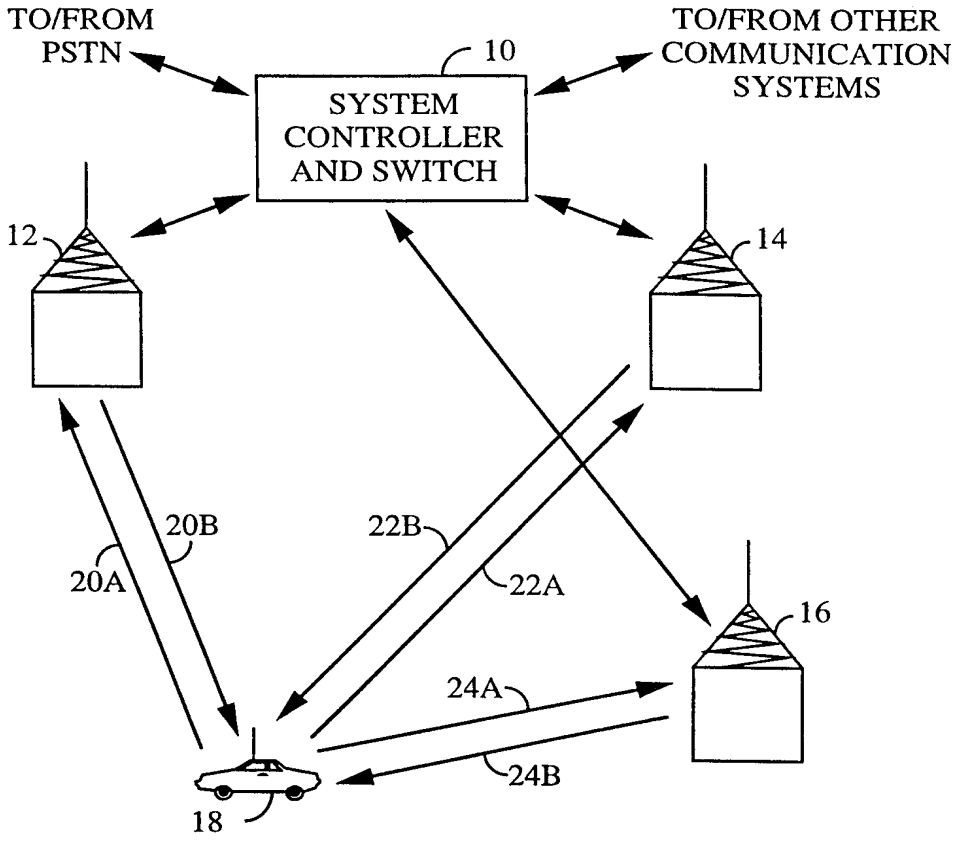
TO/FROM
PSTN
10
SYSTEM
CONTROLLER
AND SWITCH
TO/FROM OTHER
COMMUNICATION
SYSTEMS
12
14
16
18
20A
20B
22A
22B
24A
24B

FIG. 1

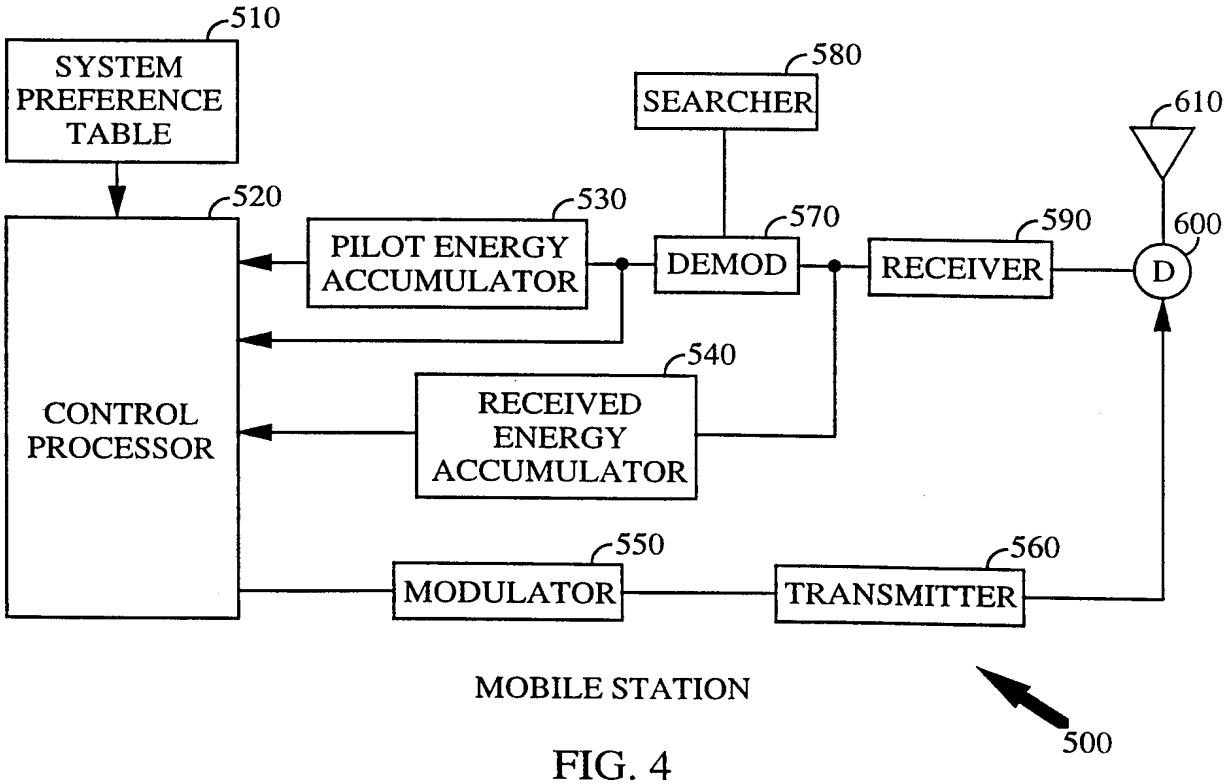
510
SYSTEM
PREFERENCE
TABLE
520
CONTROL
PROCESSOR
530
PILOT ENERGY
ACCUMULATOR
540
RECEIVED
ENERGY
ACCUMULATOR
550
MODULATOR
560
TRANSMITTER
570
DEMOD
580
SEARCHER
590
RECEIVER
600
D
610
MOBILE STATION
500

FIG. 4

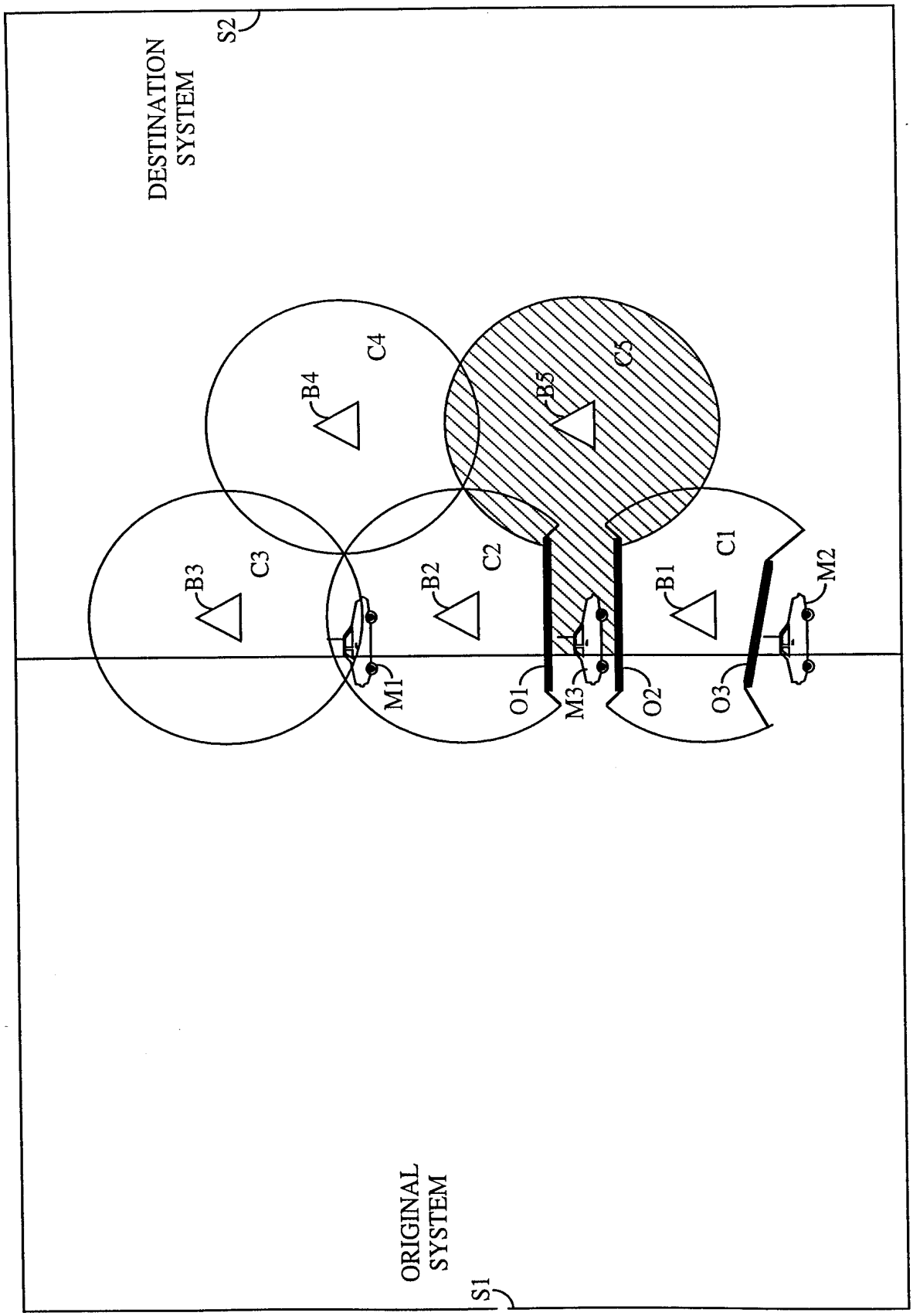
DESTINATION SYSTEM
S2
ORIGINAL SYSTEM
S1
B1
B2
B3
B4
B5
C1
C2
C3
C4
C5
M1
M2
M3
O1
O2
O3

FIG. 2

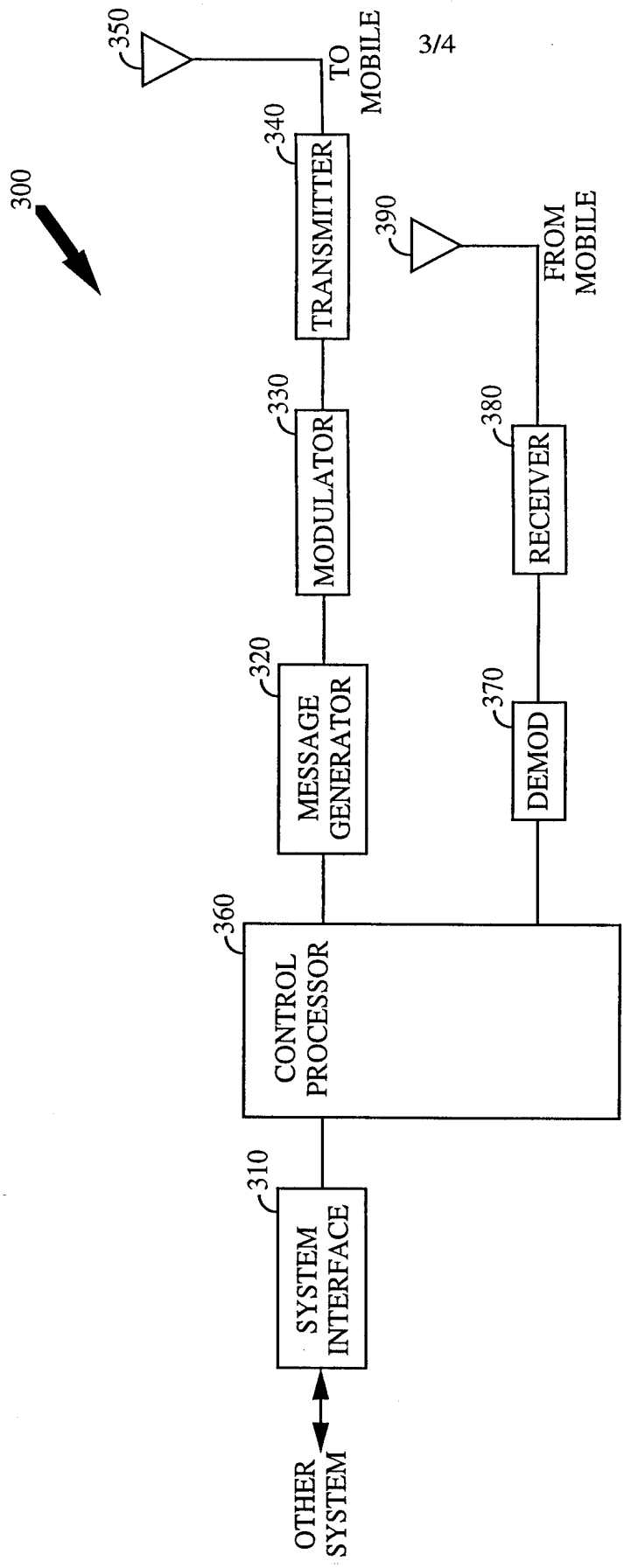
300
350
TO MOBILE
340
TRANSMITTER
390
FROM MOBILE
330
MODULATOR
380
RECEIVER
320
MESSAGE GENERATOR
370
DEMOD
360
CONTROL PROCESSOR
310
SYSTEM INTERFACE
OTHER SYSTEM
BASE STATION

FIG. 3

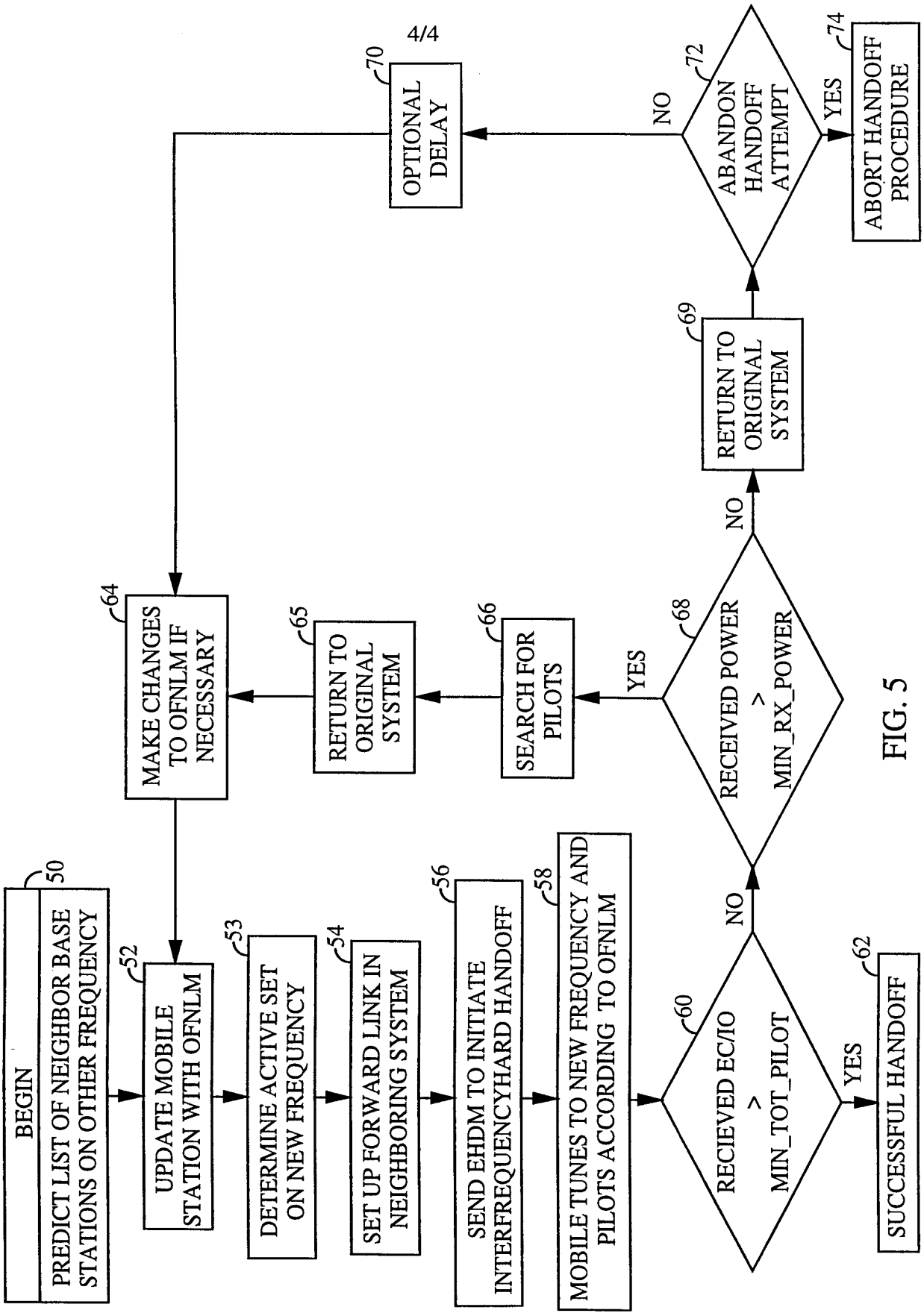
BEGIN
PREDICT LIST OF NEIGHBOR BASE STATIONS ON OTHER FREQUENCY
50
UPDATE MOBILE STATION WITH OFNLM
52
DETERMINE ACTIVE SET ON NEW FREQUENCY
53
SET UP FORWARD LINK IN NEIGHBORING SYSTEM
54
SEND EHDM TO INITIATE INTERFREQUENCYHARD HANDOFF
56
MOBILE TUNES TO NEW FREQUENCY AND PILOTS ACCORDING TO OFNLM
58
RECIEVED EC/IO > MIN_TOT_PILOT
60
YES
SUCCESSFUL HANDOFF
62
NO
RECEIVED POWER > MIN_RX_POWER
68
YES
SEARCH FOR PILOTS
66
RETURN TO ORIGINAL SYSTEM
65
MAKE CHANGES TO OFNLM IF NECESSARY
64
NO
RETURN TO ORIGINAL SYSTEM
69
ABANDON HANDOFF ATTEMPT
72
YES
ABORT HANDOFF PROCEDURE
74
NO
OPTIONAL DELAY
70

FIG. 5